Research Summary

Silane Bridge Deck Rating

Objective

Concrete bridge decks are exposed to chloride-laden deicing chemicals, repeated freeze–thaw cycles, surface scaling, abrasion, and cracking — all of which accelerate moisture and chloride ingress and drive reinforcement corrosion. This project evaluated the effectiveness and estimated service life of commercially available silane sealers and experimental silane–nanoclay composite systems for protecting concrete bridge decks, combining an extensive laboratory program with a field evaluation of four Missouri bridge decks in service for approximately eight years.

Four neat silane products on the MoDOT Approved Products List were evaluated — Protectosil SH100, Protectosil S300, Protectosil CIT, and SIL-ACT-ATS 200 — along with silane–nanoclay composites prepared by incorporating organophilic montmorillonite nanoclay at 2.5% and 5.0% loading ratios. Performance was assessed through contact angle and penetration depth, salt absorption and vapor transmission, chloride penetration in cracked and uncracked concrete, apparent chloride diffusivity, surface and bulk resistivity, rapid freeze–thaw resistance, deicing-salt scaling, capillary absorption, and water permeability. SEM, XRD, and FTIR characterized the silane–nanoclay systems.

Laboratory Findings

Silane impregnation proved an effective means of improving bridge-deck durability. Relative to untreated concrete, silane-treated specimens generally showed reduced chloride ingress, lower capillary water absorption, improved resistance to deicing-salt scaling, and reduced moisture accumulation that can lead to critical saturation during freeze–thaw exposure. Measurable differences appeared among products despite their generally similar active-ingredient contents.

- **Product performance:** Protectosil SH100 and SIL-ACT-ATS 200 gave the best overall performance, followed by Protectosil S300; Protectosil CIT was consistently the least effective. This overall ranking reflects a trade-off across mechanisms rather than a single product leading on every test: SH100 was strongest on long-term chloride penetration, chloride diffusivity, and electrical resistivity, whereas SIL-ACT-ATS 200 led on scaling resistance and capillary absorption. SH100 is therefore recommended where chloride ingress is the primary deterioration mechanism, and SIL-ACT-ATS 200 where freeze–thaw cycling and surface scaling dominate.
- **Surface resistivity:** Resistivity correlated well with chloride-penetration resistance and shows promise as a practical comparative tool. Because it is strongly affected by concrete moisture condition, measurements must use controlled, consistent conditioning. No field acceptance thresholds were established, so resistivity is best used as a comparative quality-control or screening method alongside other indicators of treatment effectiveness.

Silane–Nanoclay Composites

The composites produced mixed results. Under moderate exposure they performed well — they gave the highest freeze–thaw resistance of any system tested, reduced chloride penetration under 3% NaCl (with the benefit growing over extended exposure), and, at the 2.5% loading, improved crack sealing by narrowing the chloride difference between cracked and uncracked concrete. Under aggressive conditions, however (higher chloride concentrations and deicing chemicals), the composites showed greater chloride ingress and more surface scaling, particularly at the 5.0% loading, and they increased capillary absorption relative to neat silane through a mechanism the authors flag as not fully understood. Characterization indicated that the nanoclay's organic modifier may partially detach under high-ionic-strength exposure, which may explain the reduced performance.

On balance, the specific silane–nanoclay formulations evaluated are **not recommended for general bridge-deck surface treatment under aggressive chloride and deicing-salt exposure**, though the 2.5% formulation shows potential for localized crack and joint sealing. Further research is warranted into alternative organic modifiers, smaller particle sizes, and improved dispersion.

Estimated Service Life and Reapplication

Using the SHRP C-103 methodology, estimated service lives under non-aggressive exposure were approximately 5.4 years for Protectosil SH100 and 5.0 years for SIL-ACT-ATS 200, and 5.8 and 6.1 years for silane–nanoclay composites at 2.5% and 5.0% loadings. The composite estimates should be treated with caution: the SHRP C-103 procedure was not validated for these systems, and it accounts only for chloride-driven corrosion, not the frost-scaling and aggressive-salt weaknesses observed above. These laboratory estimates support a nominal reapplication interval of about five years following early-age treatment. Reapplication decisions should nonetheless be governed by bridge condition, exposure severity, treatment history, water absorption, chloride profiles, and residual hydrophobicity rather than elapsed time alone.

Field Evaluation and Rehabilitation Recommendations

The four decks evaluated showed considerable variability.

This variability indicates that long-term effectiveness depends not only on the product selected, but also on concrete condition at application, surface preparation, application quality, environmental exposure, traffic abrasion, initial chloride contamination, and treatment age. Field penetration depths also suggested that silane effectiveness gradually declines with time. Long-term deck-preservation programs should therefore combine properly selected silane treatments with documented application procedures and periodic condition-based performance assessment.

Implementation Conclusions

Silane sealers are effective materials for reducing moisture and chloride ingress and mitigating freeze–thaw and deicing-salt deterioration in concrete bridge decks. Protectosil SH100 and SIL-ACT-ATS 200 provided the best overall performance, with product selection guided by the dominant deterioration mechanism. Surface resistivity may serve as a comparative screening tool when moisture conditions are controlled. A nominal five-year reapplication interval is supported by the service-life analysis but should ultimately be governed by field condition assessment. The silane–nanoclay formulations investigated are not recommended for general bridge-deck application under aggressive exposure, though the 2.5% formulation showed potential for localized treatment of cracks and joints.

Recommended Highlight Statement

> *Silane treatments provide an effective strategy for reducing chloride ingress, water absorption, freeze–thaw deterioration, and deicing-salt scaling in concrete bridge decks. Protectosil SH100 and SIL-ACT-ATS 200 exhibited the best overall performance, and a nominal five-year reapplication interval is supported, subject to condition-based field assessment.*

Project Information

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